know scarcely in any one case, whether differentiation has taken place by *direct* selection of few or of many organs. When once such measurements are forthcoming we shall have firmer ground to go upon, and the processes of the present memoir seem to suggest how in the future we shall be able to link together quantitatively local races, and possibly at a more remote date obtain quantitative conceptions of the stages of evolutionary descent itself.

" On the Correlation of Intellectual Ability with the Size and Shape of the Head. (Preliminary Notice.)" Drawn up by Karl Pearson, F.R.S., University College, London. Received January 8,—Read January 23, 1902.

(1.) The collection and reduction of the material on which this preliminary notice is based were due to co-operative labour. Our aim was to ascertain which, if any, physical characters are sensibly correlated with intellectual ability. With this end in view we obtained leave from the Cambridge Anthropometric Committee to freely use their valuable series of measurements on Cambridge undergraduates. Our object was to discover whether these measurements had any relationship to the character of the degrees afterwards obtained by the measured. In order to do this it was necessary to copy the names of the persons measured, and ascertain what was the nature of the degrees ultimately obtained by them. The work of copying the names and colleges of the measured was first undertaken by Miss Mildred E. Barwell, of Girton College, and on her leaving Cambridge was continued and completed by Miss M. Beeton, of the same college. Miss Beeton prepared cards giving the name, college, and chief physical measurements of upwards of a thousand Cambridge undergraduates. This work was very laborious, and considerably increased by the number of duplicates which had to be discarded.* The next stage was to get the subject, place, and character of the degree ultimately taken by the measured placed upon the cards. The labour of tracing each individual in the publications of the University would have been

* There seems to have been a desire on the part of some of the measured to test the accuracy of the measurer by repeating the process as often as possible, and subjecting him to various artifices. One senior wrangler was measured no less than five times! Considering that the measurer had not the means of a prison warder for controlling his subject, he appears to have managed fairly well. When the duplicates were hopelessly irreconcilable—generally in those characters depending upon the agency of the subject—they were all rejected. In other cases where the differences were slight, the first measurements were taken as representative, and the later cards thrown out.

excessive, and we owe entirely to the kindness of Mr. W. H. Macaulay, of King's College, the presentation of our problem to the authorities of the University Registry and the arrangements for supplying the necessary data. We have heartily to thank both him and the officers at the Registry for aid in this matter. We thus obtained the addition to our cards of the exact nature, honours or poll, class-place, subject (science, theology, literature, &c.) of the degree taken by each individual. We were then provided with a most valuable mass of material for testing how far any of the chief physical characters are correlated with a fairly comprehensive scale of ability, or with the special intellectual tastes of the measured.

There is work in this mass of material, reducing and classifying it, for one or two good calculators during several years. At present no attempt has been made to reduce it, except in one special direction—that of the correlation of intellectual ability with the shape of the head. This is the subject of the present preliminary notice. The tables in this case were prepared partly by myself and partly by my assistant, Mr. E. Blanchard, B.A., of Caius College. Nearly the whole work of calculation is due to Dr. Alice Lee and Miss M. A. Lewenz, B.A. The conclusions, therefore, are a co-operative product of the biometric workers associated with me at University College, London.

(2.) Dr. Lee, in a paper "A First Study of the Correlation of the Human Skull," published in the 'Phil. Trans.,' A, vol. 196, pp. 225–264, has presented a considerable amount of evidence to show that "there is no marked correlation between skull capacity and intellectual power" (p. 259). We have found this result frequently contested and a very definite statement made that able men have large heads. We cannot find, however, that there are really reliable statistics, adequately treated, which in any way prove this general statement. It is perfectly true that the professional classes in this country have a rather larger head than the hand-working classes, and the former are rather more intellectual; but they are taller and physically more developed also, and the whole difference is most probably due to better nurture. One of our number, Dr. W. R. Macdonell, has recently shown that the head of the Cambridge undergraduate is larger than the head of the criminal population,[*] but any deduction from a mixture of these two classes (that ability is correlated with size of head) would be wholly misleading. We must take a homogeneous class of approximately the same nurture and habits, and inquire whether there is any correlation between ability and size of head within this class. It is this which we have attempted to do with the Cambridge statistics.

(3.) For our present purposes we have made a very broad classification of Cambridge men into poll and honours men. There are occasionally poll men who undoubtedly are intellectually stronger than some

[*] "On Criminal Anthropometry . . .," 'Biometrika,' vol. 1, pp. 185, 188, &c.

honours men. But to any one acquainted with the present Cambridge system the division thus made will appear a well-marked and distinctive one. I think the majority of college tutors would undoubtedly agree in the broad statement, that the poll man cannot be compared for intellectual ability with the honours man. Making this broad division, we are at once able to use the method of my paper : " On the Correlation of Characters not Quantitatively Measurable."*

The characters dealt with from the Cambridge measurements were (*a*) Cephalic Index ; (*b*) Length of Head ; (*c*) Breadth of Head. The classifications adopted were : for (*a*) indices under and over eighty ; for (*b*) lengths under and over 7·65 inches ; and for (*c*) breadth under and over 6·05 inches.

The following fourfold tables resulted from the classification :

(*a*.) Cephalic Index.

		Under 80.	Over 80.	Totals.
Ability.	Honours	307 ·5	216 ·5	524
	Pass	276 ·5	210 ·5	487
	Totals	584	427	1011

The correlation therefore between ability and dolichocephaly is $r = 0.0305 \pm 0.0349$.

(*b*.) Length of Head.

		Under 7″ ·65.	Over 7″ ·65.	Totals.
Ability.	Honours	264	260	524
	Pass	272	215	487
	Totals	536	475	1011

The correlation† therefore between short heads and ability is $r = -0.0861 \pm 0.0332$.

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* ' Phil. Trans.,' A, vol. 195, pp. 1–47.

† This result is due jointly to Miss M. Lewenz, B.A., and Dr. Alice Lee.

(*c.*)   Breadth of Head.

		Over 6″·05.	Under 6″·05	Totals.
Ability.	Honours	284	240	524
	Pass	250	237	487
	Totals	534	477	1011

The correlation therefore between ability and broad heads is $r = 0·0450 \pm 0·0322$. Were these results sensible we should have to conclude that ability was directly correlated with increased length and breadth, and further with a dolichocephalic tendency. But if we compare the numbers with their probable errors, we see that the correlation is non-significant in the cases of both cephalic index and breadth ; while in the case of length of head, the correlation is only two to three times the probable error, and, even if this be taken as significant, which is doubtful, the value of the correlation is so small that it can have no practical importance, when we attempt to judge ability from physical measurements of the head.*

So far then as our Cambridge results go, they thoroughly confirm Dr. Lee's investigation as to the capacity of the skull. There is no *marked* correlation between ability and the shape or size of the head.

(4.) It seemed possible—although on less safe data—to consider the same problems from our school-measurement series.† I say on less safe data for two reasons : (*a*) Because the measurements being made in schools of all types up and down the country really involve a mixture of classes with very different forms of nurture, and (*b*) Because we have to allow rather roughly for growth.

There is little doubt that the cephalic index remains sensibly constant during growth, and therefore in this character we can compare children of different ages.‡   On the other hand, the length and breadth

* [It was suggested to me when this paper was read that a better grouping would be first and second class honours men together and third class honours men with poll men. Accordingly, Miss Lewenz undertook the calculations for this division. She found the correlation between ability and short heads $-0·1066 \pm 0·0343$, and between ability and broad heads $0·0347 \pm 0·0345$. The latter correlation was thus practically unaltered, and the former increased only within the limits of the probable error.   Compare the results in the summary for honours men only.]

† This series was carried out by assistance from the Government Grant Committee.

‡ I find for Cambridge men, cephalic index $= 79·5$; for school children (*all classes*) 78·4, and Dr. Macdonell for criminal classes 78·5.   Compare also the valuable

of the head changes, and we are compelled to reduce our measurements to what they would be if the children were all of one age. Taking the length of head, Dr. Alice Lee formed a correlation table between length of head and age for 1856 boys, ranging from 4 to 19 years of age. The mean head-length was taken for each year of age, and thus a curve of average size of head of boys from 4 to 19 obtained. This curve presented several marked features, notably an apparent period of rest in growth during the 12th year.* These features will be more fully discussed on another occasion, but the rest in the 12th year is referred to here as a reason why we have chosen the 12th year as a standard age to which we may refer all our measurements. The growth of the average boy from every year up to the 12th year, and from the 12th up to every later year, was now determined. These growths were then added to or subtracted from the head-length measured on the individual in order to deduce from the observed size of the boy's head his approximate size of head in the 12th year. This, of course, is far from legitimate ; it supposes that each individual boy grows like the average boy, which we know is not the fact. Still it will not lead us very far astray for the purpose of the broad classification we are proposing.†

A precisely similar process was adopted for the breadth of head. The 12th year was still chosen for the standard age, although in this case the growth-curve from 4 to 19 years exhibits no period of rest, being almost exactly a straight line.‡

In our school observations the following classification of intelligence was adopted (it having been shown by experiment to give fairly concordant results when the same children were classed by independent observers) :—*Quick-Intelligent, Intelligent, Slow-Intelligent, Slow, Slow-Dull,* and *Very Dull.* For the purposes of our present investigation, we grouped the first two categories together and the remaining four together. We will call the first group *Intelligent* and the second *Slow,* and these may be taken to roughly correspond to our first division of *Honours* and *Poll* men when dealing with Cambridge graduates.

results on this point obtained by Dr. W. Pfitzner, 'Zeitschrift für Morphologie u. Anthropologie,' vol. 1, 1899, p. 372.

* A like but less marked rest in the 12th year is indicated in W. T. Porter's curves for growth of head in boys : see "The Growth of St. Louis Children," ' Trans. Acad. of Science of St. Louis,' vol. 6, pp. 264–380, Plate 32.

† An examination of Mr. Porter's curves of growth for the 25th, 50th, and 75th percentile grades (*loc. cit.*, Plate 32) seem to indicate (by the parallelism of these curves) how small really is the correlation between amount of growth and actual length of head.

‡ This is again in keeping with Mr. Porter's results for ages 6 to 17 ; see *loc. cit.*, Plate 33. His percentile curves are again approximately parallel, and thus favour the view that amounts of growth are largely independent of size. Why there is rest in growth of length but not in growth of breadth is an interesting problem.

The following tables resulted from this classification :—

(*a*.) Cephalic Index.

		Under 78·5.	Over 78·5.	Totals.
Ability.	Intelligent	426·75	475·75	902·5
	Slow	519·25	571·25	1090·5
	Totals	946	1047	1993

The correlation deduced from this table between ability as measured by the teacher and dolichocephaly is $r = 0\cdot0052 \pm 0\cdot0240$.

(*b*.) Length of Head.   (Reduced to 12th year.)

		Below 184·5 mm.	Above 184·5 mm.	Totals.
Ability.	Intelligent	404·5	473	877·5
	Slow	536	560·5	1096·5
	Totals	940·5	1033·5	1974

The correlation, therefore, between short heads and ability is $r = -0\cdot0437 \pm 0\cdot0242$.

(*c*.) Breadth of Head.   (Reduced to 12th year.)

		Below 145 mm.	Above 145 mm.	Totals.
Ability.	Intelligent	399·5	499	898·5
	Slow	542	545·5	1087·5
	Totals	941·5	1044·5	1986

The correlation, therefore, between ability and broad heads is $r = 0\cdot0843 \pm 0\cdot0240$.

In judging these tables we make the important assumption that the teacher's estimate of the ability of a boy at a given age is approximately correct if applied to him when 12 years old. There will of course be exceptions to this rule, but they will hardly be numerous enough to invalidate the results drawn from such broad classifications as we are here dealing with.*

These results confirm entirely the conclusions we have drawn from the Cambridge statistics. There is a non-significant correlation between dolichocephaly and ability; there are very small correlations between length and breadth of head and ability. The ability and length correlation here is about what the ability and breadth correlation was in the Cambridge case, and *vice versâ*. Hence we cannot assert that either length or breadth is dominant in the case of ability.

Summary.—If we sum up the conclusions which can be drawn from our present material, I think they would run as follows :—

We have taken two standards of ability : (i) a youth's view of his own capacity (doubtless influenced by the opinions of his parents and teachers), determined by whether he works for a pass or honours degree ; (ii) the teacher's view of the child's capacity. In neither case is there a sensible relation between ability and shape of the head as judged by the cephalic index.

In both cases there is a small correlation between the size of the head as judged by both length and breadth and the individual's ability. The mean of the values found gives $r = 0\cdot0649$ for length and ability and $0\cdot0647$ for breadth and ability, or taking these as the same, we may say that the correlation between size of head and ability is $0\cdot0648$, practically $0\cdot065$.

Let us examine this numerically to realise better its degree of significance. Consider the class of people who have an ability which occurs only in 2 per cent. of the population—a fairly high standard. Let h be their grade of intelligence and σ the standard deviation of intelligence ; so that 2 per cent. of the population have an intelligence differing from the mean by h or more. Then to find h/σ we have :

$$\tfrac{1}{50} = \frac{1}{\sqrt{2\pi}} \int_{h/\sigma}^{\infty} e^{-\frac{1}{2}x'^2}\, dx',$$

whence, by tables of the probability integral :

$$h/\sigma = 2\cdot05375.$$

Let $\bar{y}$ be the mean size of head of these exceptionally able people and σ' the standard deviation of size of head ; $r = 0\cdot065$, and $N =$ total population. Then :

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* As a teacher, I am continually struck by the accordance between one's *general* appreciation of a student's power—not necessarily on an examination-room scale— and his after-achievement in life.

$$\bar{y} = \frac{\dfrac{N}{\sqrt{2\pi}\,\sigma}\displaystyle\int_h^\infty e^{-\frac{x^2}{2\sigma^2}}\,\frac{r\sigma'}{\sigma}\,x\,dx}{\dfrac{N}{\sqrt{2\pi}\,\sigma}\displaystyle\int_h^\infty e^{-\frac{x^2}{2\sigma^2}}\,dx}$$

$$= \sigma'\frac{r\dfrac{1}{\sqrt{2\pi}}\,e^{-\frac{h}{2\sigma^2}}}{\frac{1}{5\,0}} = \sigma' \times 0\cdot 156,975.$$

Now let us find the proportion of the population which has a head as large as the mean head of the exceptionally able people. We have if n be their number :

$$n/N = \frac{1}{\sqrt{2\pi}}\int_{0\cdot 156,975}^\infty e^{-\frac{1}{2}y'^2}dy'.$$

We easily find from the tables $n/N = 0\cdot438$. Thus 44 per cent. of the population have heads as large or larger than the mean head of the exceptionally able 2 per cent. Conversely, 44 per cent. of the population are as able or abler than the 2 per cent. of the population with exceptionally big heads. When we recollect that 50 per cent. of the population would be abler or larger headed than the mean of the population, it will be recognised how small is the basis upon which we can argue from ability to largeness of head or from largeness of head to ability.

In dealing with this problem we have dealt with a normal distribution of ability in the general population. There is nothing thus far to prove a *close* relationship between ability and either shape or size of the head. If phrenology were not a discredited branch of knowledge it would be easy to investigate its claims by a like statistical method. But phrenology has not met with the same widespread acceptance among men of science as the belief that ability—brain power—is correlated with the size of the head has done. Of course if abnormal ability—genius—and abnormal dulness—crass stupidity—were *both* associated with large-headedness, our method of investigation would fail to exhibit this result. We have no means of isolating crass stupidity from the mass of poll men. But we are able to pick out from the honours men—unfortunately only 524 in number—the grades of ability corresponding to first, second, and third classes under competitive examination. I found the following distributions :

(*a*.) Cephalic Index of Honours Men.

Honours.	Under 80.	Over 80.	Totals.
1st class	88	65	153
2nd class	113 ·5	68 ·5	182
3rd class	106	83	189
Totals	307 ·5	216 ·5	524

Miss M. A. Lewenz worked out the correlation, first grouping the first and second class together, and then the second and third class to form a fourfold table. In the first case we have correlation between ability and dolichocephaly $= 0·0641 \pm 0·0487$, and in the second case $= -0·0254 \pm 0·0490$. The probable error is of the same order as the coefficients, and neither result is significant. We conclude that there is nothing whatever to show that great ability as evidenced by the competitive-examination test is related especially to either dolicho-cephaly or brachicephaly.

(*b*.) Length of Head of Honours Men.

Honours.	Under 7″ ·65.	Over 7″ ·65.	Totals.
1st class	68	85	153
2nd class	94	88	182
3rd class	102	87	189
Totals	264	260	524

Grouping first and second class together, Miss M. A. Lewenz found $r = 0·0865 \pm 0·0471$ for the correlation between great ability and long-headedness, sensibly the same as that found on p. 335, when the poll men were taken into account. Grouping second and third class together, the value of r rose to $0·1263 \pm 0·0439$, the probable error of the difference being greater than the difference. Before commenting on this I give the table for breadth of head :

(c.) Breadth of Head of Honours Men.

Honours.	Under 6″·05.	Over 6″·05.	Totals.
1st class............	58	95	153
2nd class	95	87	182
3rd class	87	102	189
Totals	240	284	524

Grouping first and second class together Miss M. A. Lewenz found $r = .0\cdot0056 \pm 0\cdot0475$ for the correlation between great ability and breadth of head ; while when the second and third classes were grouped together r rose to $0\cdot1689 \pm 0\cdot0478$, the probable error of the difference being thus sensibly less than the difference. Now if such a small number as 524 can be trusted there would thus seem to be an increasing correlation between ability and size of head, when we isolate the exceptional men who take first-class honours.[*]   But when we note the size of the probable error of these results, and see how comparatively small they are, it seems possible to attribute their divergence from the previous values to other sources than the relation of genius to size of head.   Notably we must bear in mind that head length and breadth increase throughout life ;[†] and that the honours men as a whole are older than the poll men and older in the first than in the second class—a considerable number of resident dons being included in this series of measurements—men of high honours and considerable age.   Hence I think we can lay only slight stress on the apparent increase of correlation as we isolate the more brilliant men. We must finally conclude that : Very brilliant men may possibly have a very slightly larger head than their fellows, but taking the general population there is really a very insignificant association between size of head and ability.   For practical purposes it seems impossible, either in the case of exceptionally able men or in the bulk of the population, to pass any judgment from size of head to ability or *vice versâ*.

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[*] The alteration of correlation with the alteration of the class divisions shows that the frequency surface is not accurately normal. In the *general* Cambridge undergraduate population, as well as in the criminal classes, the head measurements give normal curves within the limits of random sampling. See Macdonell, *loc. cit.*, p. 181, *et seq.*

[†] W. Pfitzner, ' Zeitschrift für Morphologie u. Anthropologie,' vol. 1, p. 365.